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An assessment of household water insecurity in a rapidly developing coastal metropolitan region of Indonesia

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ABSTRACT

Water security in the Cirebon Metropolitan Region (CMR) is under threat from regular flood and drought events, rapid urbanisation and climate change. This study used the Guttman's scale approach to assess household water insecurity in the CMR. Factor and cluster analyses were then applied to confirm the results and identify issues that shaped household water insecurity in four urbanisation levels in the CMR, namely urban, urban/peri-urban transition (UPT), peri-urban, and rural. Data were obtained through surveys of 225 farm households and 205 non-farm households using face-to-face interviews. The study shows spatial variations of water insecurity concerning urbanisation and farm and non-farm households. The study indicates that dominant factors shaping household water insecurity in the CMR are (i) unacceptable levels in water risks and (ii) inadequate water sources and services to satisfy the population's needs in relation to health, livelihood, ecosystems, and production. Flooding in the region significantly affects water insecurity of UPT farm and non-farm households, while droughts affect rural farm and non-farm households. The methodology used in this study provides an analytical framework to better understand socio-ecohydrological issues underpinning farm and non-farm household water insecurity and for developing an evidence-based water security policy in a rapidly urbanising region.

1. Introduction

Water security in coastal metropolitan regions in developing Asian countries is under threat from many sources; these include rapid population growth and urbanisation, the increasing rate of groundwater extraction and land subsidence, declining water quality, water-related disasters and climate change. There is evidence that these factors have compromised household water security in rapidly urbanising regions in Asia (Asian Development Bank, 2013a). Indonesia is not a water-scarce country; however, infrastructures, environmental management, and land use planning are not keeping pace with the rapid growth of urban development which leads to increasingly water insecure households (Asian Development Bank, 2013b, 2016a, 2016b, 2016c; Deltares, DHV, MLD, & Wiratman, 2012).

These issues are well documented in the case studies done on large coastal cities such as Jakarta. Household water security in this metropolis has been threatened by the low coverage of piped water and sanitation services; excessive groundwater pumping; alarming land subsidence; decreasing water quality; and increasing climate-related disasters (Abidin et al., 2011; Delinom et al., 2009; Firman, Surbakti, Idroes, & Simarmata, 2011; Palupi et al., 1995; Steinberg, 2007). Increasingly, attention has turned to studying smaller coastal cities such as Cirebon and Makassar, with the findings indicating similar issues and higher concerns about the capacity of institutions to effectively manage rapid urbanisation and climate change pressures (Fahmi, Hudalah, Rahayu, & Woltjer, 2014; Rositasari, Setiawan, Supriadi, Hasanuddin, & Prayuda, 2011; Tjandraatmadja et al., 2012, 2013).

Water is a critical element in achieving the Sustainable Development Goals (SDGs), particularly Goal 6, to ensure availability and sustainable management of water and sanitation for all (UN, 2018). The Asian Development Bank (2016b) reports that the proportion of Indonesian households with access to improved water supply is 67%, mostly being obtained from protected dug well (29.2%), bore well (24.1%) and piped water (19.7%). Centralised sewerage systems are limited to a few cities and less than 5% of sewage is properly treated resulting in massive pollution of surface and groundwater sources.

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While the need to make water security more risk and opportunity-oriented has been defined (Grey & Sadoff, 2007), the current thinking in water security is still largely focused on infrastructure. Recently, the Government of Indonesia prioritised providing access to piped water supply services and to communal and central sanitation facilities as critical measures for obtaining household water security. However, it is not clear whether this strategy will be effective in Java where approximately 60% of residents live in water insecure regions with frequent floods and droughts (Asian Development Bank, 2016b; Deltares et al., 2012; Yusuf & Francisco, 2009).

This study aims to better understand household water insecurity in the context of the dynamic nature of socio-ecological-hydrological interactions that characterise the insecurity of an urbanising region. Specifically, it: (i) identifies the major concerns of residents regarding water insecurity resulting from urbanisation that shapes ecohydrological change; (ii) investigates whether limited access to water and sanitation infrastructures significantly shapes farm and non-farm household water insecurity in a rapidly developing coastal metropolitan region in Java; (iii) identifies dominant factors and issues that shape household water insecurity in this region at different urbanisation levels; and (iv) develops an analytical framework for assessing farm and non-farm household water insecurity to identify diverse situations in urban and peri-urban areas. Additional comparisons are made in the discussion section to similar cases in other cities/countries.

2. Theoretical and conceptual frameworks

2.1. Water security definition

Water security is termed in various perspectives. These include sustainability (Global Water Partnership, 2000), development and risk (Garrick & Hall, 2014; Grey et al., 2002; Grey & Sadoff, 2007), equity of access related to human rights (Bradley & Bartram, 2013), biodiversity (Vorosmarty et al., 2010), anthropocentric orientation (Stevenson et al., 2012), gender disparity (Wutich, 2009), vulnerability and adaptation (Scott et al., 2012), and the complexity of water-society challenges (Zeitoun et al., 2016). This water security study was applied in the context of sustainability, development, and risk.

In the frame of sustainability, water security, at any level from the household to the global, is defined broadly as "*Access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced*" (Global Water Partnership, 2000). Further, in the frame of development and risk, water security is defined broadly as "*The availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies*" (Grey & Sadoff, 2007).

The two definitions were deemed the most appropriate for the study as they address human and ecosystem needs, accessibility, continuity, and affordability as well as provision and risk perspectives. These provide the framework for actions to ensure human and ecosystem health, to provide improved domestic water and sanitation, to decrease the proportion of people who are water-insecure, and to achieve better management (Asian Development Bank, 2016a; Bradley & Bartram, 2013; Cook & Bakker, 2012; Global Water Partnership, 2000).

For our purpose, these two definitions were conceptualised in the context of a water insecure region. We defined household water insecurity as "*Insufficient accessibility and capability of water sources and services to satisfy the household needs for health, livelihood, ecosystem, and production, coupled with inadequate acceptability and adaptive capacity of households to deal with the ecohydrological changes that impact liveability and sustainability*". Liveability in this study is understood in the context of socio-ecohydrology that refers to dynamic interactions between people, water, and the environment; sustainability refers to long-term liveability that is ensured via planning and management interventions (Danielaini, Maheshwari, & Hagare, 2018d).

2.2. Water security assessments

2.2.1. Assessment of water security in the context of urbanisation and climate change

There are an increasing number of studies on urbanisation and climate change and their impacts on water systems, management, and security (Astaraie-Imani, Kapelan, Fu, & Butler, 2012; Gebremeskel, Liu, De Smedt, Hoffmann, & Pfister, 2004; Jaramillo & Nazemi, 2017; Meenu, Rehana, & Mujumdar, 2013; Islam & Thian Yew, 2014; Neumann, Tjandraatmadja, Kironob, & Selitung, 2013). However, relying on reductionist or simplified approaches such as modelling are not sufficient to address the complex socio-ecological and socio-hydrological challenges related to the interactions between people, water, and the environmental (Byg & Salick, 2009; Wesselink, Kooy, & Warner, 2017). A complex or integrative approach that does not seek to generalise the complexity of human-water-ecological challenges is required. In this study, this is achieved by combining comparative research with deeper contextualising work on how local variations occur considering existing knowledge (Zeitoun et al., 2016). In this case, understanding historical experiences help to test theories of human-environment interactions and can be used for guiding future actions in promoting water security to support sustainable urban development.

2.2.2. Assessment of water security through indices versus experience-based scale

Several studies to assess water security have been conducted from using one-variable measures to using several variable measures as a composite index (Asian Development Bank, 2013a; Chaves & Alipaz, 2007; Gleick, 1996; Norman, Dunn, Bakker, Allen, & de Albuquerque, 2013; Sullivan, 2002; Sullivan, Meigh, & Giacomello, 2003). Single variable measures, such as water access or water quality or water infrastructures, have been assessed as being inadequate to capture the multifaceted nature of water security (Wheater & Gober, 2013). Composite indexes that incorporate several interdependent dimensions of water security into one are also not sufficient to understand diverse and complex water security issues (Lautze & Manthrithilake, 2012).

Another approach that incorporates several variables to assess water security is experience-based scales or scalograms or Guttman scaling. Guttman scalograms record frequently positive responses, from higher to lower, as well as rank individuals in relation to those responses (Guttman, 1944). This scaling method can be used for widespread applications to quantify qualitative data from attitude and opinion surveys (Clark & Kriedt, 1948), for example, to rank household wealth (Guest, 2000), measure consumer behaviour (Ekinci & Riley, 2000), and assess patients with health issues in mobility disability (Souza, 1999). Recently, Guttman scaling has been used to address household water insecurity (Wutich & Ragsdale, 2008; Hadley & Wutich, 2009; Jepson, 2014). Guttman scaling procedures assess the cumulative or progressive experiences and do not seek to generalise patterns across different socio-economic groups (Wutich & Ragsdale, 2008).

2.3. Assessment of household water insecurity

Water insecurity at a household level falls within the domain of human development (Jepson, 2014). It can be associated with difficulty in accessing water or issues with the affordability, adequacy, and quality of water for social productivity and a healthy life which is contrary to human rights (Gleick, 1998; Global Water Partnership, 2000; UNESCO, 2006). Further, water insecurity assessment at a regional level is within the vulnerability and risk domain and can be associated with climate and hydrological changes (Scott et al., 2013). The assessment of household water insecurity in this study combined those related indicators and used community perspectives/experiences in the urban and peri-urban areas to examine socio-ecohydrological change resulting from rapid urbanisation.

A recent measurement of household water insecurity using the

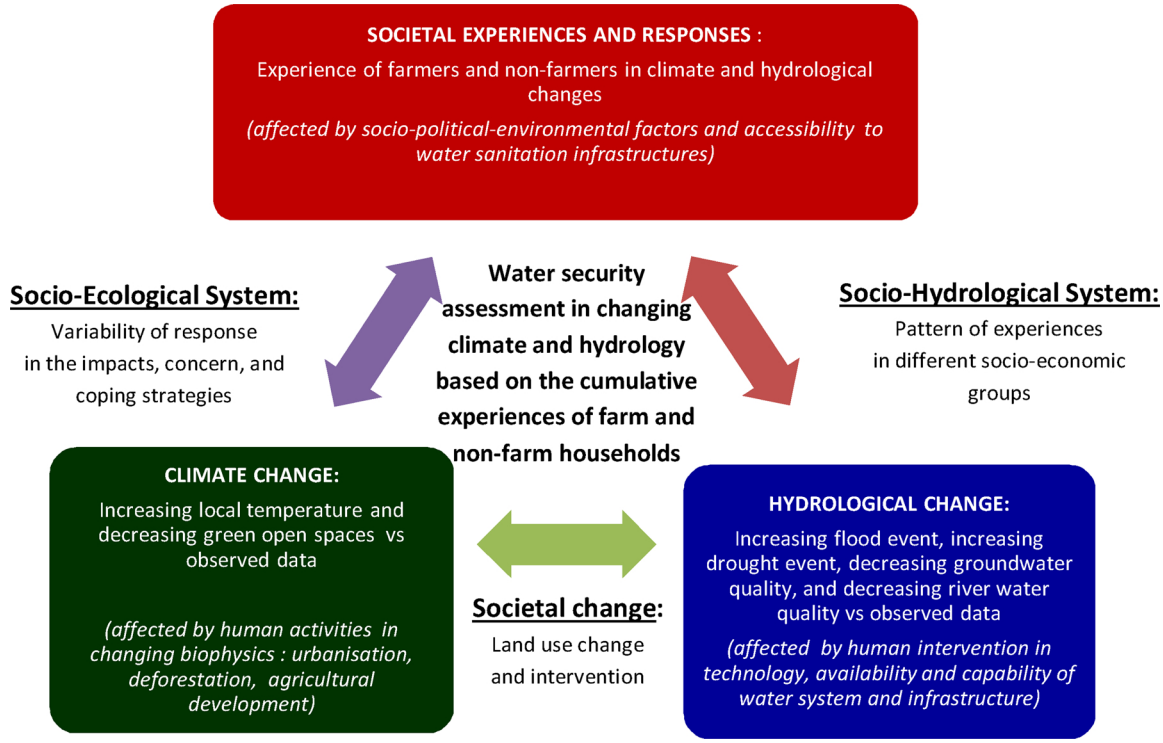
SOCIETAL EXPERIENCES AND RESPONSES :
Experience of farmers and non-farmers in climate and hydrological changes
(affected by socio-political-environmental factors and accessibility to water sanitation infrastructures)
Socio-Ecological System:
Variability of response in the impacts, concern, and coping strategies
Water security assessment in changing climate and hydrology based on the cumulative experiences of farm and non-farm households
Socio-Hydrological System:
Pattern of experiences in different socio-economic groups
CLIMATE CHANGE:
Increasing local temperature and decreasing green open spaces vs observed data
(affected by human activities in changing biophysics : urbanisation, deforestation, agricultural development)
Societal change:
Land use change and intervention
HYDROLOGICAL CHANGE:
Increasing flood event, increasing drought event, decreasing groundwater quality, and decreasing river water quality vs observed data
(affected by human intervention in technology, availability and capability of water system and infrastructure)

Fig. 1. Analytical framework for water security study in the CMR.

Guttman's scale as developed by Jepson (2014) identifies issues of household water access, acceptability and its effect on the urban fringe. However, the indicators that focus on domestic water provision are not sufficient to describe household water (in)security as they should include access to piped water systems, improved sanitation, and hygiene (Asian Development Bank, 2013a). Water also has a critical function in the economic productivity of farm households. Further, any assessment of household water security in the urban system at the regional scale will need to consider the changes in land use, water cycle, and climate; all of which relate to livelihood, environmental protection, community resilience and urban liveability (Danielaini, Maheshwari, & Hagare, 2018e).

This study advances previous work on experience-based scaling of household water security. We used an analytical framework at different urbanisation levels in a coastal region, which included accessibility to water and sanitation infrastructures; acceptability of water risks from ecohydrological change; capability of socio-ecohydrological systems to satisfy the needs for health, livelihood, ecosystem, and production; and household adaptive capacity in dealing with the impacts resulting from socio-ecohydrological change (Fig. 1).

3. Material and methods

3.1. Study Area

The Cirebon Metropolitan Region (CMR) is located in the north-eastern corner of the West Java Province. It consists of 45 sub-districts: five sub-districts located in the Cirebon City, 31 sub-districts located in the Cirebon District, five sub-districts located in the Kuningan District, three sub-districts located in the Majalengka District, and one sub-district located in Indramayu District. The total area of the five districts is approximately 3426 km^2. The CMR covers 32% of this area, has a population of more than 2.4 million and is situated between 0 and 857 m above sea level (Regional Development Planning Board of West Java Province, 2015). In the past two decades, this region has experienced rapid urbanisation indicated by a strong decrease of paddy fields combined with an increase of housing and surroundings (Verburg, Veldkamp, & Bouma, 1999).

In this northern coastal region of West Java, economic stress in rural agricultural areas rather than increased economic opportunities in the urban areas has exacerbated urbanisation (Winoto & Schultink, 1996). However, the region has not been provided with sufficient ecohydrological protection, including adequate water and sanitation infrastructures, and this significantly decreases the ecohydrological based liveability of residents (Danielaini et al., 2018d). Climate change has also affected the urban and rural areas and residents within CMR (Pratiwi, Ardhyarini, Rahmawati, & Setiono, 2017; Rositasari et al., 2011), with several studies reporting frequent floods and droughts in this region (Daruati, Rahmatulloh, & Purwadhi, 2013; Sagala, Yamin, Pratama, & Rianawati, 2014; Pratiwi et al., 2017). While quantitative data about infrastructure at a regional scale are available, little is known at the local level about the complex experience of water insecurity concerning urbanisation and farm/non-farm households.

3.2. Data collection

This study incorporates perspectives from city and peripheral city dwellers in the CMR to examine water security issues. The total area of the CMR is 1080 km^2 with 73% of it being located in the Cirebon City and Cirebon District (Regional Development Planning Board of West Java Province, 2015). Hence, the survey was concentrated in these areas, around 70% of the total surveyed households (N = 430). The proportion of surveyed households in the city is 23%, while in the peripheral city is 77%. This percentage represents the proportion of the population living in the urban sub-districts which are approximately 21% of the total population in the CMR (Danielaini, Maheshwari, & Hagare, 2018c; Regional Development Planning Board of West Java Province, 2015).

A cross-sectional survey using face-to-face interviews was conducted with 225 farm householders and 205 non-farm householders across five districts and 25 sub-districts (Fig. 2). The 430 households were selected through a three-step process: First, consultation at the

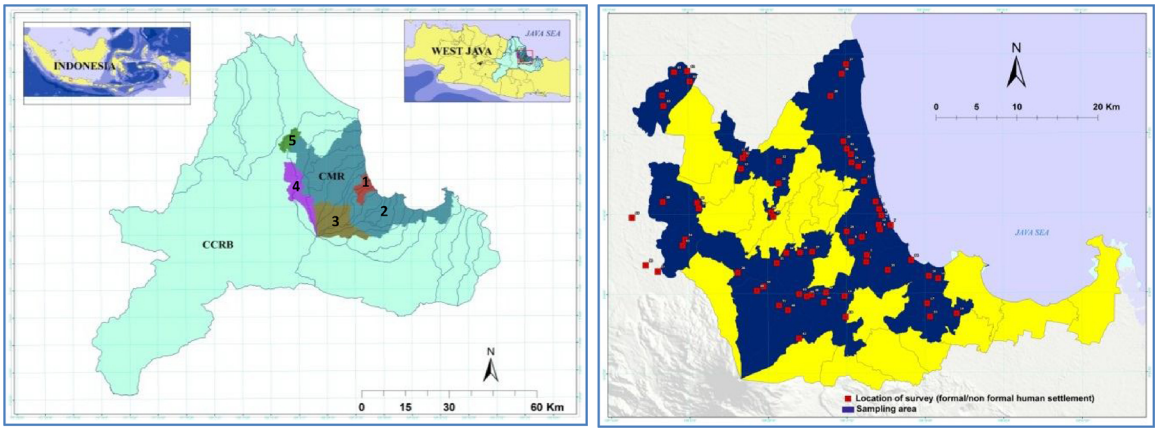

Fig. 2. Location of the Cirebon Metropolitan Region (CMR) within the Cimanuk-Cisanggarung River Basin (CCRB) and sampling areas for study.
Note: Administrative political boundary at district level within CMR: 1. Cirebon City; 2. Cirebon District; 3. Kuningan District; 4. Majalengka District; 5. Indramayu District.

district level to identify the sub-districts experiencing impacts of eco-hydrological change. Second, another consultation at the selected sub-districts, representing various distances from the coast, to identify villages experiencing water issues and potential sampling areas. Third, a field trip at the village level to apply a random walk method in different directions from the village head office, as a starting point. Before conducting survey in the village, we met the village head/community leader/the head of farmers group to obtain information about the situation of the village and to identify potential places where most farmers and non-farmers live or work. We also surveyed households in Majalengka District along the road between Sumberjaya/Leuwimunding Sub-district and Jatiwangi Sub-district following the information from local residents. They noticed that rapidly land use change occurs in that place. The survey sites were then extended to accommodate the might impact of urbanisation close to the outer boundary of CMR.

Sample households were randomly selected at certain distances from the starting point, by walking following the road or path. Three trained enumerators with experience in taking a census helped gather the survey data. Interviews were conducted at the same village at any given time, with the enumerators approaching different homes at different directions from the starting point. The survey aimed to grasp diverse experiences of communities regarding the change of socio-ecohydrological aspects. Only one household was selected randomly at one point. The second household was selected randomly at a further distance from the starting household. If the second householder provided relatively similar responses as the first householder, the survey moved to another village. In case of scattered areas, we were assisted by a local guide to show the path leading to households. In several surveyed locations, the head of the farmers group invited his members to gather in one place, although we did not ask him to do so. Hence, we randomly chose the research participants, one participant per enumerator being interviewed. In addition, we did some interviews outside homes. Most paddy farmers were not at home in the morning while most fishermen were not at home in the evening. Hence, some interviews of the farmers were conducted at the rice fields while interviews of the fishermen were conducted on boats; when they took a break from work.

In a narrow definition, farm households can be defined as households that were mainly dependent on farming for their livelihoods. Farming plants or animals, either on land (agriculture) or in water (aquaculture), involve interventions to enhance production such as regular stocking, feeding and protection from predators and also implies ownership of the stock being cultivated (2018, FAO, 1997). Fishermen capture fish and the activities of hunting fish/fishing are part of the fisheries sector. In this study, all surveyed households that actively engaged in agricultural activities such as farm cultivation, husbandry and poultry, aquaculture, and fish capture were categorised as farm-households. This study followed a broad definition of farm households as all households with main income sources from agricultural sub-sectors including food crops, horticulture, estate crops, livestock, fishery and forestry (Garner & de la O Campos, 2014; FAO, 2013; Achmad, 2010).

On average, interviews took 30 min. Prior to each interview, each participant was informed about the objective of the survey and given general information about the study. Written informed consent was obtained from the participants who agreed to be interviewed. Closed and open-ended questions were delivered during the household survey and the interviews. The questions were delivered in different formats to obtain detailed information on socio-ecohydrological aspects in the region. For example, open-ended questions included “To what extent have ecohydrological functions changed in the past 10 to 20 years?” and “Are there any concerns regarding the change in land use, water cycle and climate? Please specify….”. This information was used to assess how householders’ positive or negative experiences would inform their responses to the statements of household water insecurity, such as “I have concerns regarding the change in land use, water cycle, and climate from future urbanisation”, “Climate and hydrological changes adversely affect household social and economy”.

Closed-ended questions about water sources for drinking listed various possible responses, including bottled water, piped water into dwellings, piped water into yards, public taps, tube well/boreholes, protected dug wells, unprotected dug wells, protected springs, unprotected springs, rainwater and other (surface water, small carts, tanker trucks). The information given by the participant was assessed in the format of positive/negative responses to the statement for assessing household water insecurity, such as “Household members do not have access to improved drinking water sources”. If the farmer/non-farmer, as a representative of the household, reported that drinking water was sourced from bottled water/unprotected dug well/unprotected spring/surface water/other, we assessed that response as a positive response to the statement, while if they reported from a piped water/ public tap/ tube well/ borehole/ protected dug well/ protected spring, we assessed that response as a negative response to the statement.

JMP (2017a) has recognised that packaged water and delivered water can potentially deliver safe water, and can be classified as limited, basic or safely managed. However, in this study, we categorised bottled water and delivered water as unimproved facilities due to (i) limitations in the potential quantity, not quality, of the water and (ii) the lack of data on accessibility, availability, and quality, following the JMP criteria (JMP, 2017a, b, Yu et al., 2016). In addition, according to Ferrier (2001), bottled water should not be considered as a sustainable alternative to tap water.

Another example, the close-ended question about the capability of

water-related services for satisfying the needs for health, livelihood, ecosystem, and production used a 5-point Likert scale (1 = very unsatisfied; 2 = not satisfied; 3 = unsure; 4 = satisfied; 5 = very satisfied). The responses from the participants were also assessed in the format of positive/negative responses to the statement for assessing household water insecurity. For instance," Currently not satisfied with healthy waterways" or" Currently not satisfied with drought prevention" or" Currently not satisfied with income". If the participants selected 1 or 2, that response was assessed as a positive response to the statement, while if they selected 3 or 4 or 5, that response was assessed as a negative response to the statement.

Ethical approval for the survey was granted by the Western Sydney University (WSU) Human Research Ethics Committee with the approval number **H11417**. Recommendation letters for the survey were also obtained from the WSU, the Indonesian Ministry of Home Affairs, the West Java Province and the Local Governments of Cirebon City, Cirebon District, Kuningan District, Majalengka District, and Indramayu District.

3.3. Data analysis

Open-ended questions were coded and categorised using NVivo Pro (QSR)™ 11.0 as it is useful for analysing texts from semi-structured interviews and is suitable for organising and interpreting qualitative data (Sotiriadou, Brouwers, & Tuan-Anh, 2014). Quantitative data analysis from questionnaires, namely (i) factor and cluster analyses of household water insecurity were conducted using SPSS (IBM)™ version 25 and (ii) Guttman scale analysis was conducted using Anthropac 4 (Borgatti, 1996). Different typology groups were developed based on the level of urbanisation namely urban, urban/peri-urban transition (UPT), peri-urban, and rural (Danielaini, Maheshwari, & Hagare, 2018b). The selected indicators follow Chaves (2012) recommendation that meaningful water security indicators should include cause and effect relationships that cover the pressure-state-response approach such as climate and human pressures, water quantity and quality, state and societal responses.

The survey questions addressed 33 indicators within four dimensions of water security namely access, acceptability, capability and adaptive capacity from the urban and peri-urban communities or beneficiary's perspectives in the regional development areas. Responses were assessed in dichotomous scale, zero for negative responses and one for positive responses. Responses and individual households were then re-arranged in the data matrix. The experience-based indicators used in the scale development are shown in the idealised Guttman scales (Table 1).

Reliability tests for each scale were calculated using three conventional measures namely minimal marginal reproducibility (MMR) that should be less than 0.90, the coefficient of reproducibility (CR) more than 0.85, and coefficient of scalability (CS) greater than 0.60 (Guest, 2000; Wutich & Ragsdale, 2008; Hadley & Wutich, 2009). The responses and internal consistency and reliability of the water security assessment using the cumulative experiences of four Guttman scales and 33 indicators were moderately acceptable (0.68-0.71). However, the reliability tests for each scale of water security dimension with CR and CS values were less than acceptable, indicating that the selected statements did not follow the scale procedures to rank questions based on difficulty or cumulative progressive experiences. This indicated the need to focus on capturing diverse related experiences and existing situations within one dimension of water security (Table 2).

As a comparison, the 33 indicators were also assessed using factor analysis with principal components for unidimensional tests (Table 3). Factor analysis was applied as the alternative analysis of the multi-dimensional scale analysis. Household water (in)security classification was determined using cluster analysis from both approaches on different socio-economic groups, based on four urbanisation levels, and farm and non-farm households. Hierarchical cluster analysis was used to define the number of clusters through a dendrogram and the K-mean cluster analysis was used to define water (in)security classification.

4. Results

4.1. Residents experiences in ecohydrological change concerning urbanisation

The 225 farm and 205 non-farm householders represented a diversity of demographic characteristics in the study area (Table 4). Their experiences regarding socio-ecohydrological change and impacts in their places revealed different concerns of water insecurity in the urban, UPT, peri-urban, and rural areas (see Fig. 1 in Danielaini, Maheshwari, and Hagare, (2018a). The figure depicts word clouds of the100 most frequent display words that people said within rural-urban interfaces that indicate that urban residents were most likely to talk about the insufficient capability of public drinking water services to satisfy their needs, UPT residents were most likely to talk about floods, and peri-urban and rural residents were more likely to talk about the dry season and droughts.

4.2. Typology of water security issues based on the Guttman scale and cluster analyses

Idealised Guttman scale revealed that householders without private sanitation facilities are likely to have limited access to other water-related infrastructures. Householders who experienced increasing flooding events are likely to have experiences in decreasing water quality and open spaces. Householders who were unsatisfied with flood protection are likely to be not satisfied with unhealthy environments. Householders who do not use water efficiently are likely to disagree with minimising water consumption. From the Guttman scale analysis (Table 5), water security was classified into four clusters, namely Water Secure (S1), Marginally Water Secure (S2), Marginally Water Insecure (S3), and Water Insecure (S4).

The largest percentages of urban households (44.6%) and non-farm households (40.0%) are water secure (Fig. 3). Among the four clusters, those households have the best access to water sources and services, but they may have problems in water risk acceptability. Additionally, the highest proportion of UPT, peri-urban, and rural households (> 33%) and farm households (39.6%) are marginally water secure. Households in this cluster may have problems in access to water sources and services. On the other hand, more than 25% of UPT and rural households and 22.7% of farm households are marginally water insecure. Households in this cluster have the poorest water risks acceptability. Further, 24.7% of rural households and 21.3% of farm households are water insecure. Households in this cluster have the poorest water and sanitation access, water system capability and household adaptive capacity.

Further analyses, see Tables 1–3 in Danielaini et al. (2018a), indicate that households in the rural, peri-urban, and UPT areas have significantly higher insufficient access to water-sanitation infrastructures than those in the urban area ($p < 0.001$). This is particularly true for farm households. UPT households have the highest unacceptable water-related risks. However, there are no statistically significant differences in water risk acceptability between UPT households and rural, peri-urban and urban households ($p > 0.05$). This is particularly true for both farm and non-farm households in the UPT area. In water system capability, rural households have the lowest water system capability compared to the other three urbanisation level categories. This is particularly true for farm households in the rural area. Urban households have the highest level of inadequate adaptive capacity to ecohydrological change but it is not statistically significantly different than that in the other three categories ($p > 0.05$). This is particularly true for farm households in the urban area. In general, farm households have significantly higher water insecure situations than that of farm households.

Table 1
Idealised Guttman scales for assessing household water insecurity.

No	Selected Indicators for data analysis	Responses									
1a	**Idealised Guttman Scale for insufficient accessibility to water sources and related services**										
1	Household does not have private sanitation facilities	No	No	No	No	No	No	No	No	yes	
2	Household does not have private water facilities	No	No	No	No	No	No	No	yes	yes	
3	Household members do not have access to improved non-drinking water sources	No	No	No	No	No	No	yes	yes	yes	
4	Drainage system is not available surrounding household	No	No	No	No	No	yes	yes	yes	yes	
5	Household members do not have access to improved drinking water sources	No	No	No	No	yes	yes	yes	yes	yes	
6	Household members do not have access to improved sanitation facilities	No	No	No	yes	yes	yes	yes	yes	yes	
7	Household does not have access to public drinking water system	No	No	yes	yes	yes	yes	yes	yes	yes	
8	Household does not have access to public waste water treatment system	No	Yes	yes	yes	yes	yes	yes	yes	yes	
	Score	0	1	2	3	4	5	6	7	8	
	Definition	Score									
	Adequate water-sanitation access – A1	0-1									
	Marginal water-sanitation access – A2	2									
	Low water-sanitation access – A3	3-4									
	Very low water-sanitation access – A4	5-8									
1b	**Idealised Guttman Scale for inadequate acceptable level to water risks resulting from ecohydrological change**										
9	Having experience an increase in flood event	No	No	No	No	No	No	No	No	No	yes
10	Currently having problem in flood/flooding	No	No	No	No	No	No	No	No	yes	yes
11	Having experience a decrease in groundwater quality	No	No	No	No	No	No	No	yes	yes	yes
12	Currently having problem in groundwater quality	No	No	No	No	No	No	yes	yes	yes	yes
13	Currently having problem in water scarcity/drought	No	No	No	No	No	yes	yes	yes	yes	yes
14	Having experience an increase in drought event	No	No	No	No	yes	yes	yes	yes	yes	yes
15	Having experience an increase in temperature	No	No	No	yes	yes	yes	yes	yes	yes	yes
16	Having experience a decrease in river water quality	No	No	yes	yes	yes	yes	yes	yes	yes	yes
17	Having experience a decrease in green open spaces	No	yes	yes	yes	yes	yes	yes	yes	yes	yes
	Score	0	1	2	3	4	5	6	7	8	9
	Definition	Score									
	Highly likely water risks acceptability – B1	0-1									
	Marginal water risks acceptability – B2	2-3									
	Low water risks acceptability – B3	4-6									
	Very low water risks acceptability – B4	7-9									
1c	**Idealised Guttman Scale for insufficient capability of water sources and services to satisfy the needs for health, livelihood, ecosystem, and production**										
18	Currently not satisfied with flood protection	No	No	No	No	No	No	No	No	No	yes
19	Currently not satisfied with healthy housing	No	No	No	No	No	No	No	No	yes	yes
20	Currently not satisfied with housing with garden spaces	No	No	No	No	No	No	No	yes	yes	yes
21	Currently not satisfied with healthy human settlement	No	No	No	No	No	No	Yes	yes	yes	yes
22	Currently not satisfied with sufficient water availability	No	No	No	No	No	yes	Yes	yes	yes	yes
23	Currently not satisfied with water and sanitation infrastructures	No	No	No	No	yes	yes	Yes	yes	yes	yes
24	Currently not satisfied with drought prevention	No	No	No	yes	yes	yes	Yes	yes	yes	yes
25	Currently not satisfied with healthy waterways	No	No	yes	yes	yes	yes	Yes	yes	yes	yes
26	Currently not satisfied with income	No	yes	yes	yes	yes	yes	Yes	yes	yes	yes
	Score	0	1	2	3	4	5	6	7	8	9
	Definition	Score									
	High intervention capability for satisfying socio-economic activities – C1	0									
	Marginal intervention capability for satisfying socio-economic activities – C2	1-3									
	Low intervention capability for satisfying socio-economic activities – C3	4-6									
	Very low intervention capability for satisfying socio-economic activities – C4	7-9									
1d	**Idealised Guttman Scale for inadequate household adaptive capacity to cope with the ecohydrological change**										
27	Disagree that it is important to use water much more efficient			No	No	No	No	No	No	No	yes
28	Disagree that it is important to minimise water use consumption			No	No	No	No	No	No	yes	yes
29	Having opinion that only government who has responsibility for improving ecohydrological status*			No	No	No	No	No	yes	yes	yes
30	Water sources and related services are liveability aspects that household members are least satisfied*			No	No	No	No	yes	yes	yes	yes
31	Having no solution to minimise the impacts of climate and hydrological changes*			No	No	No	yes	yes	yes	yes	yes
32	Climate and hydrological changes adversely affect household social and economy*			No	No	yes	yes	yes	yes	yes	yes
33	Having concerns regarding the change in land use, water cycle, and climate from future urbanisation*			No	yes	yes	yes	yes	yes	yes	yes
	Score			0	1	2	3	4	5	6	7
	Definition	Score									
	High household adaptive capacity to deal with ecohydrological changes – D1	0-1									
	Marginal household adaptive capacity to deal with ecohydrological changes – D2	2-3									
	Low household adaptive capacity to deal with ecohydrological changes – D3	4-5									
	Very low household adaptive capacity to deal with ecohydrological changes – D4	6-7									

Adapted from Jepson (2014) and Hadley and Wutich (2009). Most data of statements were obtained from closed-ended questions except *, coding from open-ended questions.

Table 2
Validity and reliability tests.

Validity and Reliability Tests	Water security dimensions			
	Access	Acceptability	Capability	Adaptive Capacity
Construct Validity (Spearman Correlation)	All statements are significantly correlated at 0.01 level (2-tailed) to total cumulative experiences at each dimension of water security			
MMR	0.74	0.72	0.68	0.73
CR	0.84	0.80	0.77	0.79
CS	0.36	0.27	0.30	0.25
Cronbach's Alpha for each scale	0.54	0.47	0.74	0.22
Lambda 2 (Guttman) for four scales	0.71			
Lambda 3 (Guttman) for four scales	0.68			
Cronbach's Alpha for four scales	0.68			

4.3. Typology of water security issues based on the factor and cluster analyses

From the factor analysis with principle component approach (Table 6), water security was classified into eight clusters, namely Very Highly Water Secure (F1), Highly Water Secure (F2), Water Secure (F3), Marginally Water Secure (F4), Marginally Water Insecure (F5), Water Insecure (F6), Highly Water Insecure (F7), and Very Highly Water Insecure (F8). Fig. 4 shows that the proportion of very highly water insecure households is highest in the areas affected by urbanisation, namely UPT (41.9%), urban (34.7%), and peri-urban (27.5%). Flood events combined with climate change may have significantly affected this group (see Table 6). On the other hand, in the areas not affected by the urbanisation process, a larger percentage of households are highly water insecure (49.3%). Drought events, combined with climate change, may have significantly affected this group. Farm households have the highest proportion of the highly water insecure category (30.7%) while non-farm households are in the very highly water insecure category (37.6%).

Further analyses, see Tables 4–6 in Danielaini et al. (2018a), indicate that households in the rural area experience significant higher drought event than those in the peri-urban, UPT, and urban areas ($p < 0.001$). They also have significantly lower water access ($p < 0.001$) and poorer sanitation facilities ($p < 0.01$) than urban households. Similarly, peri-urban and UPT households have significantly lower water access ($p < 0.001$) than urban households. This is particularly true for farm households. Compared to the households in the other three categories, peri-urban households have a significant issue with decreasing water resource availability ($p < 0.001$) while UPT households have a significant issue with flood events ($p < 0.001$). This is particularly true for farm and non-farm households in both areas. Urban households have significant higher affordability to access improved water sources and services ($p < 0.05$) but unhealthier housing and environment ($p < 0.05$) than peri-urban households. This is particularly true for non-farm households.

5. Discussion

5.1. Socio-ecohydrological issues affecting water insecurity

It is evident that flood and drought events frequently occurred in the CMR affecting liveability, and that water security is being reported as the most important aspect for liveability in the CMR (Danielaini et al., 2018e, d). The findings of this study indicate that household water insecurity is a critical challenge in this coastal metropolitan region. Limited access to water and sanitation infrastructure is a pressing problem of water insecurity in the rural, peri-urban and UPT areas, particularly for farm households. However, compared to the issues of water risks acceptability and water system capability, the issue of water and sanitation access has a less significant impact on shaping water insecurity in the CMR. In particular, this study found that floods, droughts, climate change, the concern of water risks resulting from urbanisation and climate change, and unhealthy housing and environment significantly influenced water insecurity. Flood events significantly affected water insecurity of farm and non-farm households in the urban expansion area of the CMR while drought events significantly affected that of farm households in the peripheral city, particularly within the rural area.

This finding aligns with a global assessment that floods and drought remain the two biggest threats to water security worldwide particularly in Indonesia, Guyana, and Brazil (Webb & Iskandarani, 1998). In Indonesia, floods have become a major problem in large metropolitan regions, particularly in areas of Java such as Jakarta, Bandung, and Semarang; floods and drought combined affected 32% of the total cultivated areas; Java was the most affected island (Asian Development Bank, 2016b). In many places around the world, urbanisation is the main driver behind increasing exposure of urban areas to floods and droughts which is further amplified by climate change (De Sherbinin, Schiller, & Pulsipher, 2016; Guneralp, Guneralp, & Liu, 2015). The cause of flooding in the CMR is relatively similar to larger coastal metropolitan regions in Indonesia, such as Jakarta, namely inadequate public services for flood protection, drainage systems, poor waste management practices that have not kept pace with population and urban growth (Akmalah & Grigg, 2011; Steinberg, 2007). Although the urban centre of CMR has agricultural areas of less than 15% of the city land, the peripheral city is still dominated by agricultural land (56%), making this metropolitan region sensitive to drought (Danielaini et al., 2018b).

5.2. Household water insecurity in the rural-urban interfaces

This study identifies spatial variations of household water insecurity concerning urbanisation level and type of household, farm and non-farm categories that may not appear in the assessment at a national level (Table 7). Farm households are the most water insecure due to drought (*in the rural area*), unregulated water use (*in rural and urban areas*), limited access to water infrastructure (*in the rural, peri-urban, UPT areas*), poor sanitation (*in the rural area*), water resources issues (*in the peri-urban area*), and poverty/vulnerability (*in the peri-urban area*), while non-farm households are the most water insecure due to unhealthy housing and environment (*in the urban area*), flood events (*in the UPT area*), poor affordability to access available water-related services (*in the peri-urban area*), water affect issue or unsatisfied with the intervention capability to provide access to water sources and services (*in the urban area*), climate change (*in the UPT area*), and concern of future risks (*in the UPT area*).

This study identified an interesting finding that even in the peri-urban CMR, where water and natural resources are relatively abundant (Danielaini et al., 2018c), water security could not be obtained on its own. Most householders in the peri-urban area who are marginally

Table 3
Factor analysis of selected water security indicators.

	Selected indicators for assessing water (in) security in changing climate and hydrology	PC1 Drought event	PC2 Unhealthy housing & environment	PC3 Unregulated Water use	PC4 Limited access	PC5 Flood event	PC6 Poor affordability	PC7 Poor sanitation	PC8 Water resources issue	PC9 Water affect issue	PC10 Climate change	PC11 Concern of future risks	PC12 Poverty/ vulnerability
1	Household members do not have access to improved drinking water sources			0.3			0.3		−0.4				
2	Household members do not have access to improved non-drinking water sources						0.8						
3	Household does not have private water facilities						0.8						
4	Household members do not have access to improved sanitation facilities							0.8					
5	Household does not have private sanitation facilities							0.4					0.5
6	Household does not have access to public drinking water system				0.6								
7	Household does not have access to public waste water treatment system				0.5			0.5					
8	Drainage system is not available surrounding household				0.6								
9	Currently having problem in water scarcity or drought	0.8											
10	Currently having problem in flood/ flooding					0.8							
11	Currently having problem in groundwater quality				−0.5								
12	Having experience a decrease in green open spaces								0.6				
13	Having experience an increase in temperature										0.6		
14	Having experience a decrease in groundwater quality							0.3	0.3			0.4	
15	Having experience a decrease in river water quality								0.7				
16	Having experience an increase in flood event					0.8							
17	Having experience an increase in drought event	0.7											
18	Currently not satisfied with sufficient water availability	0.7											
19	Currently not satisfied with housing with garden spaces		0.5										
20	Currently not satisfied with healthy housing		0.9										
21	Currently not satisfied with healthy human settlement		0.9										
22	Currently not satisfied with healthy waterways		0.5									0.4	
23	Currently not satisfied with flood protection					0.4							
24	Currently not satisfied with drought prevention	0.8											

(*continued on next page*)

Table 3 (*continued*)

	Selected indicators for assessing water (in) security in changing climate and hydrology	PC1 Drought event	PC2 Unhealthy housing & environment	PC3 Unregulated Water use	PC4 Limited access	PC5 Flood event	PC6 Poor affordability	PC7 Poor sanitation	PC8 Water resources issue	PC9 Water affect issue	PC10 Climate change	PC11 Concern of future risks	PC12 Poverty/ vulnerability
25	Currently not satisfied with income	0.3	0.3										
26	Currently not satisfied with water and sanitation infrastructure	0.5						0.3					
27	Having opinion that only government who has responsibility for improving ecohydrological status												0.7
28	Disagree that it is important to minimise water use consumption			0.9									
29	Disagree that it is important to use water much more efficient			0.9									
30	Water sources and services are liveability aspects that household members are least satisfied									0.8			
31	Climate and hydrological changes adversely affect household social and economy									0.7	0.3		
32	Having no solution to minimise the impacts of climate and hydrological changes									0.3		0.4	
33	Having concern of the change in land use, water cycle, and climate from future urbanisation											0.7	
	Lambda 2 (Guttman)	0.76	0.73	0.79	0.49	0.62	0.59	0.54	0.36	0.43	0.29	0.27	0.13
	Eigenvalues	3.77	2.64	1.98	1.93	1.52	1.46.	1.36	1.33	1.24	1.15	1.11	1.01
	Percentage of explained variance	11.4	8.0	6.0	5.8	4.6	4.4	4.1	4.0	3.8	3.5	3.4	3.1

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Note:

a. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = 0.67;

b. Bartlett's test: Approx. Chi-square = 2994.6; df = 528; Sig. $<$ 0.001;

c. Cronbach's alpha coefficient of total 33 indicators 0.68;

d. Cumulative variance explained from the 12 factors with eigenvalues $>$ 1 is 62.2%.

Table 4
Socio-demographic features of farm and non-farm households.

Attributes	Parameter	Percentage from total 430 households		
		Farm-household (%)	Non-Farm household (%)	Total (%)
Place in five districts within CMR (*political boundaries*)	Cirebon Municipality	7.5	15.1	22.6
	Cirebon Regency	27.0	22.5	49.5
	Indramayu Regency	4.4	2.6	7.0
	Kuningan Regency	8.6	5.4	14.0
	Majalengka Regency	4.9	2.1	7.0
Level of urbanisation	Rural	10.5	6.5	17.0
	Peri-urban	27.0	15.3	42.3
	Urban-Peri-urban Transition (UPT)	7.4	9.8	17.2
	Urban	7.4	16.1	23.5
Gender	Male	35.8	24.9	60.7
	Female	16.5	22.8	39.3
Length Stay	≤ 30 years	15.3	21.4	36.7
	More than 30 years	37.0	26.3	63.3
Distance from the coast	≤ 10 km	20.2	28.2	48.4
	More than 10 km	32.1	19.5	51.6
Household size	≤ 3 persons	14.0	11.9	25.9
	4-6 persons	32.9	28.8	61.7
	More than 6 persons	5.4	7.0	12.4
Total participants in each group		52.3	47.7	100

water secure (41.2%), may have problems with water access. According to Danielaini et al. (2018d), formal networked water systems are available in the several surveyed peri-urban sub-districts, but the majority of its residents could not afford these services, and mostly rely on groundwater or surface water which decreases in quantity during the dry season. Factor analysis confirms this finding; limited access, poor affordability, and water resource issues are the problems of water insecurity for the peri-urban households in the CMR.

Similarly, although formal networked water systems are available in the surveyed rural area, most householders in Kapetakan have issues in access and water system capability in providing acceptable water quality and quantity. The piped water supply flowing to Kapetakan had issues associated with tap water taste, its odour, its physical characteristics and not running during the dry season (Danielaini et al., 2018d). Not surprisingly, bottled water use for drinking was found highest in the surveyed rural area (53%), where most residents experienced water scarcity and droughts (56%) and were unsatisfied with water and sanitation facilities (60%). On the other hand, access to formal networked water services is not the issue of urban householders but they are still having issues on acceptable water quantity. The piped water flowing to Cirebon City sources water from a spring in the peri-urban area (Danielaini et al., 2018e). The survey found that tap water in certain areas of Cirebon City, such as in Kejaksan and Harjamukti, often flowed intermittently that was inextricably linked to low pressure and insufficient water source availability during the dry season. This issue commonly occurs in many urban regions in developing countries (Allen, Dávila, & Hofmann, 2006; Khatri, Vairavamoorthy, & Porto, 2008; Lee & Schwab, 2005). The finding is similar with the case study on low-income communities along the United States of America(USA)-Mexico border, South Texas (Jepson, 2014). Water connections in that place are available if residents can afford them but connections do not guarantee adequate water availability in quality and quantity.

5.3. Why do the water insecurity classification results differ?

The reason for different classification results might be due to different aspects of multi-dimensional water security that contributes to the household water security classification. Guttman scales require unidimensionality but water security is a multi-dimensional and complex problem (Jepson, 2014; Hadley & Wutich, 2009). Although the scalograms have been widely used for assessing attitudes and opinion surveys including objective and subjective water security perspectives, the selected four scales in this study obtained poor internal reliability scores for water access, acceptability and adaptive capacity; except for capability of water-related services for satisfying socio-economic activities. This test shows that the selected 33 indicators do not adequately fit within the four unidimensional scales, rather within the 12 unidimensional scales as obtained from the factor analysis with principal components. Underlying structures of the selected indicators show the variability of socio-ecological-hydrological systems in the CMR which shape household water insecurity. The underlying factors, from highest to lowest variance explained, were defined as drought,

Table 5
Mean values for Guttman scale scores and differences among water security clusters from four scalograms.

Water security classification	Code	Water-sanitation access		Water risks acceptability		Water system capability		Household adaptive capacity		Households (HH)	% total surveyed HH
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Water secure	S1	1.4	1.0	**3.7**	1.4	1.3	1.2	2.8	1.3	119	27.7%
Marginally water secure	S2	**3.8**	1.0	2.9	1.3	1.5	1.1	2.7	1.2	147	34.2%
Marginally water insecure	S3	2.4	1.3	**5.9**	1.0	**5.3**	1.6	2.9	1.2	88	20.5%
Water insecure	S4	**3.9**	1.5	**3.7**	1.4	**5.5**	1.3	**3.3**	1.4	76	17.7%
F		119.9		105.7		332.5		3.7			
Sig		< 0.001		< 0.001		< 0.001		< 0.05			

SD = Standard Deviation. Highlighted highest scores in bold indicate water security issues.

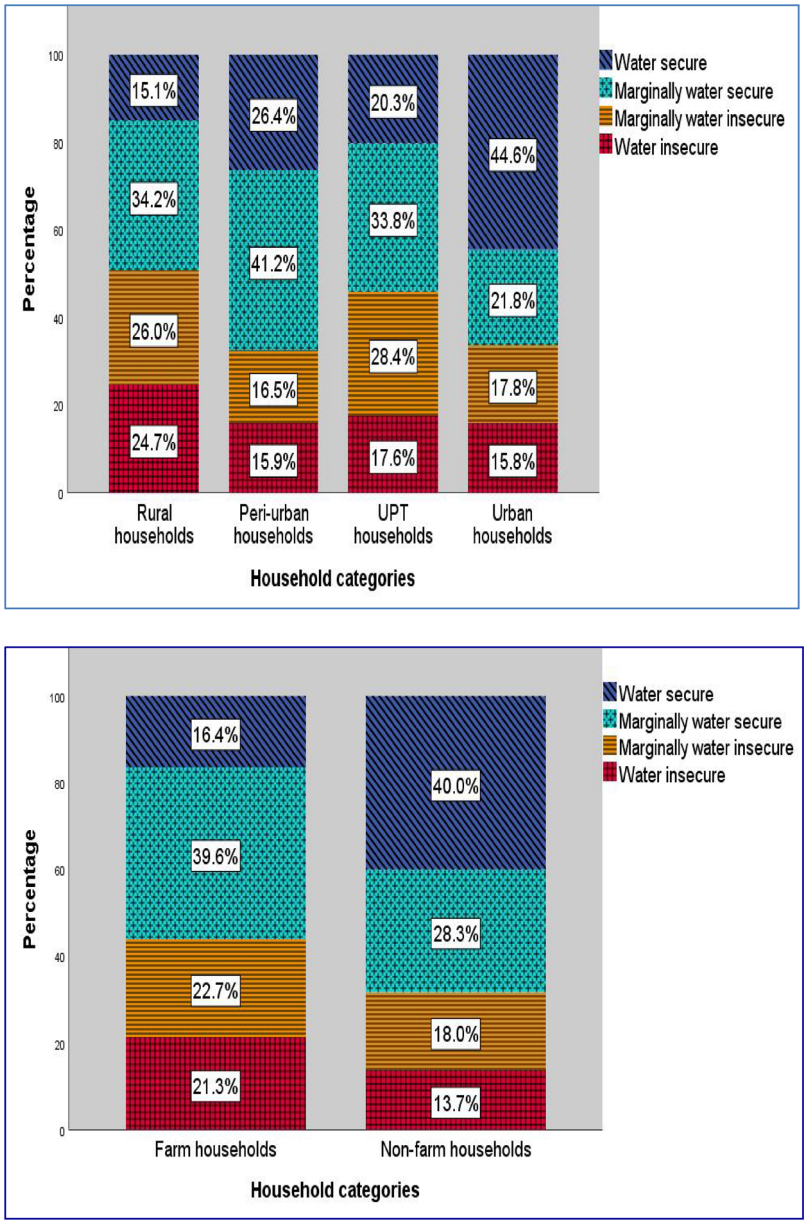

Fig. 3. Water security status of rural-urban and farm-non-farm households in the CMR from clustering four scalograms.

unhealthy housing and environment, unregulated water use, limited water access, flood, poor affordability, poor sanitation, water resources issue, water affect issue, climate change, the concern of future risks and poverty/vulnerability. However, the classification of water security from clustering four and 12 scales are able to explain the existing situation of farm and non-farm household water insecurity in the rural-urban interfaces of the CMR.

5.4. Implication of this study to water security policy in the water insecure region

The results revealed water security variability among farm and non-farm households at four urbanisation levels in the CMR. These findings present the need for local government to assess the entire range of government interventions in dealing with household water insecurity resulting from urbanisation, and to understand the impacts on farm and non-farm households in the rural-urban interfaces. This includes the need to reframe the government's approach to water supply and monitoring at a household scale. This information is particularly important for developing policies and strategies to enhance regional water security and resilient urban systems for sustainability, particularly for strategic planning in the rural-urban interface areas. Beneficiary perspectives as shown in this study can provide a pathway for the government to obtain a situation whereby a management program can be accepted, satisfying community water needs and achieving a positive evaluation in all relevant water security aspects.

This typical water insecure region like parts of Southern China, sub-Saharan Africa, South and Southeast Asia, has considerable complex interactions with biophysical, social, economic and political aspects, including risks and uncertainties that need more investment in information, infrastructures and capacity of institutions to deal with the relatively high costs of infrastructure and innovation (Grey et al., 2002). In addition, local perceptions and participation need to be taken into account when introducing new technologies in water infrastructures and management as shown in White Mountain and Shishmaref, Alaska (Marino, White, Schweitzer, Chambers, & Wisniewski, 2009), Nunavik, Canada (Martin et al., 2007), Palomas and Ojinaga, along the USA-Mexico Border (Pena & Cordova, 2001), and Central

Table 6
Mean values for factor scores and differences among water security clusters from factor analysis.

Water security classification		Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6	
		Drought event		Unhealthy housing & environment		Unregulated Water use		Limited access		Flood event		Poor affordability	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Very highly water secure	F1	−1.6	0.7	0.1	1.4	**2.3**	0.6	−0.7	0.2	−0.7	0.3	2.0	1.7
Highly water secure	F2	−0.4	1.4	0.1	1.3	1.2	1.2	−1.1	1.0	0.2	0.7	−0.2	0.4
Water secure	F3	0.3	1.0	−0.5	0.6	−0.6	0.6	0.4	0.8	0.0	1.0	**3.0**	0.8
Marginally water secure	F4	0.1	1.0	0.0	0.9	1.4	1.2	**0.7**	1.0	−0.1	0.7	−0.1	0.8
Marginally water insecure	F5	0.1	0.9	**0.5**	1.3	−0.2	0.9	−0.1	0.9	−0.1	0.9	2.3	1.0
Water insecure	F6	0.0	1.0	0.3	1.1	−0.1	0.8	−0.9	0.9	−0.3	0.8	−0.1	0.5
Highly water insecure	F7	**0.5**	1.0	0.2	1.1	−0.5	0.3	0.1	0.9	−0.2	0.7	−0.4	0.5
Very highly water insecure	F8	−0.5	0.7	−0.3	0.8	−0.4	0.3	−0.1	0.9	**0.4**	1.3	−0.2	0.4
F		12.9		4.9		74.9		17.2		5.3		119.9	
Sig		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001	

Water security classification		Factor 7		Factor 8		Factor 9		Factor 10		Factor 11		Factor 12		HH	%HH
		Poor sanitation		Water resources issue		Water affect issue		Climate change		Concern of future risks		Poverty/ vulnerability			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Very highly water secure	F1	2.4	0.6	**1.4**	0.4	**1.4**	0.6	0.1	0.9	−1.5	1.2	**3.2**	0.5	3	0.7%
Highly water secure	F2	**2.9**	0.4	−0.1	1.4	0.7	1.0	−0.6	1.0	−0.7	0.8	**3.2**	0.7	6	1.4%
Water secure	F3	−0.1	0.8	−0.7	0.9	0.2	1.0	−0.1	0.9	0.6	0.6	0.5	0.9	18	4.2%
Marginally water secure	F4	−0.3	0.8	0.0	1.0	0.2	1.1	−0.1	1.0	0.0	0.9	−0.3	0.8	78	18.1%
Marginally water insecure	F5	−0.1	0.9	0.6	0.8	−0.8	0.8	0.0	1.0	−0.5	1.0	−0.1	0.8	15	3.5%
Water insecure	F6	0.8	0.9	0.6	0.8	0.0	1.1	−0.5	1.1	**1.1**	0.8	−0.7	0.9	60	14.0%
Highly water insecure	F7	0.0	0.9	−0.7	0.9	0.1	1.0	**0.2**	1.0	−0.2	0.9	0.2	0.8	122	28.4%
Very highly water insecure	F8	−0.4	0.8	0.4	0.8	−0.2	0.9	**0.2**	0.9	−0.3	0.9	0.1	0.8	128	29.8%
F		26.1		21.9		4.5		4.0		19.9		28.8			
Sig		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001		< 0.001			

Note: Highlighted highest scores in bold indicate underlying factors causing water insecurity.

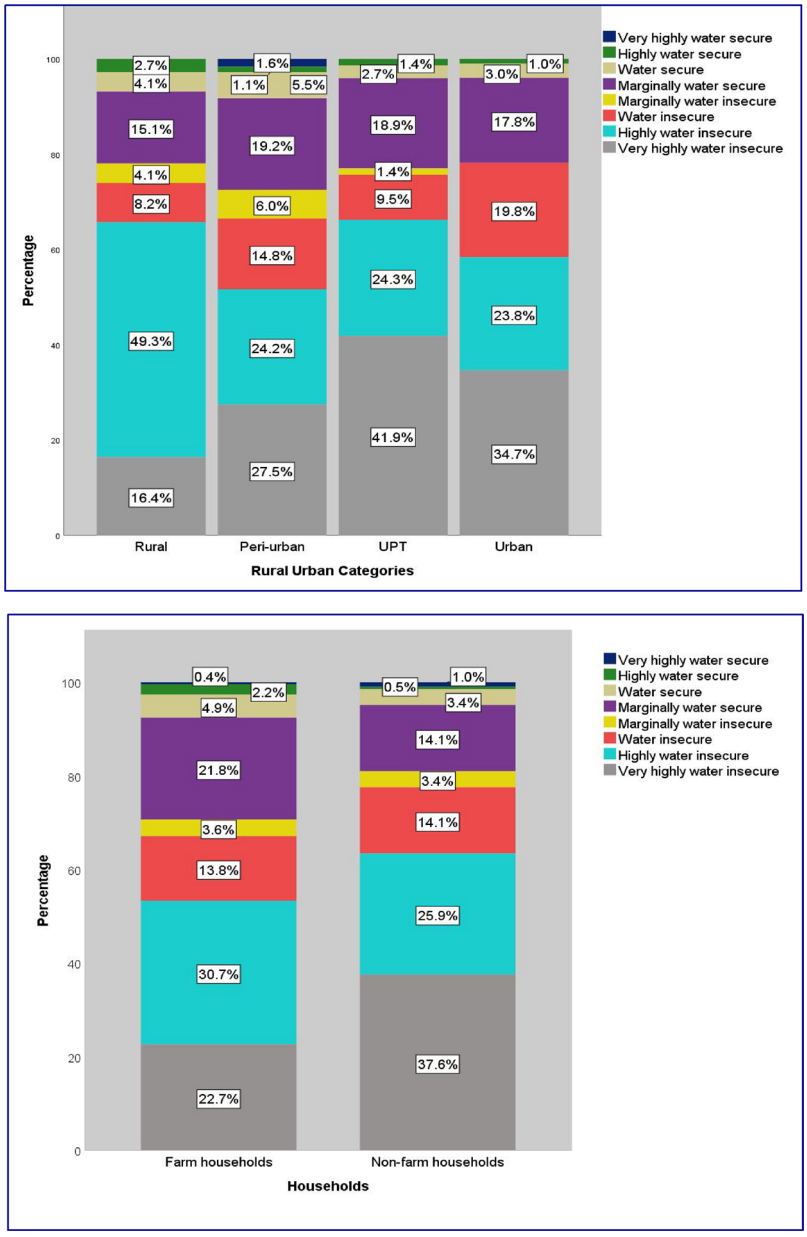

Fig. 4. Water security status of rural-urban and farm-non-farm households in the CMR from clustering factor scores.

Table 7
Typology rural-urban of farm and non-farm households in relationship with water security status in the CMR.

Experiences and classification of water security from the surveyed households		Typology farm and non-farm households (HH) in the rural-urban CMR (N = 430) and water security status (%)							
		Rural farm HH	Peri-urban farm HH	UPT farm HH	Urban Farm HH	Rural non-farm HH	Peri-urban non-farm HH	UPT non-farm HH	Urban non-Farm HH
Water security classification from the cumulative scores of four scalograms or Guttman scales	S1	17.8	18.1	12.5	12.5	10.7	40.9	26.2	59.4
	S2	28.9	44.8	34.4	40.6	42.9	34.8	33.3	13.0
	S3	24.4	19.8	34.4	18.8	28.6	10.6	23.8	17.4
	S4	28.9	17.2	18.8	28.1	17.9	13.6	16.7	10.1
Water security classification from factor scores or factor analysis of 33 selected indicators	F1	–	0.9	–	–	–	3.0	–	–
	F2	4.4	1.7	3.1	–	–	–	–	1.4
	F3	4.4	6.9	3.1	–	3.6	3.0	2.4	4.3
	F4	17.8	20.7	21.9	31.3	10.7	16.7	16.7	11.6
	F5	2.2	5.2	3.1	–	7.1	7.6	–	–
	F6	8.9	14.7	9.4	21.9	7.1	15.2	9.5	18.8
	F7	46.7	25.9	21.9	34.4	53.6	21.2	26.2	18.8
	F8	15.6	24.1	37.5	12.5	17.9	33.3	45.2	44.9
Total		100	100	100	100	100	100	100	100

Java, Indonesia (Roma & Jeffrey, 2010).

The findings of this study suggest that providing access to water and sanitation infrastructures will not be sufficient to obtain household water security in this region. The measures should include the provision of a tolerable level of water-related risk to mitigate floods and droughts, coupled with providing an acceptable level of water sources and services to the communities. This includes regulating water usage, eradicating poverty to increase affordability, improving socio-ecohydrological systems, and reducing inequality between urban and peri-urban services. Currently, there is a big gap in the availability of water services. Cirebon City has service coverage of more than 85% while the other four districts have less than 25% (WJP-MDM, 2013). This study confirms disparities in water insecurity between urban and peri-urban households, not only in access to water infrastructures but also in drought events, affordability, flood events, sanitation infrastructure, and water resource availability. Disparities in water insecurity also exist between farm and non-farm households. This study, thus, confirms that water insecurity is not uniform across localities nor across population groups (Jepson, 2014; Webb & Iskandarani, 1998).

The present study advances previous work based on scaling of household water security at a regional scale. In particular, this study advances water security study in the context of planning for balanced urban development to achieve longer-term liveability or sustainability (Maheshwari, Singh, & Thoradeniya, 2016). Nevertheless, more efforts for better understanding the dynamics of the inter-relationship between humans and water in terms of water security are still required to solve issues related to drought, floods, institution policy and management, public health and sanitation (Lall, Davis, Scott, Merz, & Lundqvist, 2017). Further, more case studies and interdisciplinary understanding will be important to provide quantification of socio-political parameters and to understand diverse water security issues (James & Shafiee-Jood, 2017). It is important to note that combining qualitative and quantitative methods needs to be considered for advancing household water security assessment and measurement methods as well as for obtaining a more holistic water security concept (Wutich et al., 2017).

6. Conclusions

This study shows spatial variations of water insecurity in the CMR, water insecure region, concerning urbanisation and farm and non-farm households. This study identified that the major concerns of residents in water insecurity are the capability of water services in urban area, flooding in the UPT area, water resources issue in the peri-urban area and drought in the rural area. Farm households are relatively the most water insecure compared to non-farm households. Providing access to water and sanitation infrastructures will not be sufficient to obtain household water security in this region. The measures should include providing a tolerable level of water-related risk, to mitigate floods and droughts, coupled with providing an acceptable level of water sources and services to the communities. This study also identifies the need to include regulating water usage, eradicating poverty to increase affordability, improving socio-ecohydrological systems and reducing inequality between urban and peri-urban services and between farm and non-farm households.

This study has demonstrated how Guttman scaling and factor analysis, combined with clustering methods, can be used to evaluate the water security issues of farm and non-farm households in the urban and peri-urban areas. The first approach of this study considered four water security dimensions, namely access, acceptability, capability, and adaptive capacity. With this approach, 38.2% of the surveyed households are water insecure as they have an inadequate acceptable level to water risks and insufficient capability of water sources and services for health, livelihood, and ecosystem. The largest percentage of water insecure households were found in the typology of UPT households (46%) followed by rural households (50.7%). There are limitations found in the coefficients of reproducibility and scalability that were below the acceptable range as there is a compromise to be made by researchers between lower validity of measurement and important indicators' exclusion. Application of scalograms under different socio-cultures within diverse complex rural/urban communities might be the cause of this limitation.

The second approach of this study was conducted through a factor analysis which revealed 12 underlying socio-ecohydrological aspects contributing to household water insecurity in the selected region. Six factors were found reliable to be contributing to water insecurity in the rural-urban environment of the region, namely drought, unhealthy housing and environment, unregulated water use, flood, poor affordability, and poor sanitation. Diverse complex socio-ecohydrological system in the metropolitan region might be the cause of low lambda 2 scores for the other six factors. With this approach, the majority of the surveyed households (75.6%) are water insecure as they have problems related to floods, droughts, climate change, the concern of water risks resulting from urbanisation and climate change, and unhealthy housing and environment. The largest percentages of water insecure households due to flood and climate change were found in the typology of UPT households (> 37%) while the largest percentages of water insecure households due to drought and climate change were found in the typology of rural farm and non-farm households (> 46%). The study shows that household water security classifications from the factor analysis can be used to validate the classification results from the Guttman scaling.

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